Photosynthesis and competition between two co-occurring invasive forest plants

Heather McMahon and Janet A. Morrison

Biology Department, TCNJ, Ewing, NJ

Abstract

Alliaria petiolata and *Microstegium vimineum* are two non-native plant species that invade forests in the North Eastern United States. Both grow in a wide range of light environments and colonize together in mixed stands. Study plots with both species present were established at Washington Crossing State Park. Light levels, percent cover, and photosynthesis rate were measured in each plot for each species. Cover of *M. vimineum* was greater per plot than cover of *A. petiolata*, and decreased with light level, while *A. petiolata* percent cover was unrelated to light levels. In July and September, *M. vimineum* had greater mean photosynthesis rates than *A. petiolata*. However, *A. petiolata* matched those higher rates during its rapid spring growth, measured in April before *M. vimineum* had germinated. In a greenhouse experiment, *M. vimineum* exhibited an overall higher photosynthesis rate, as well as the ability to increase photosynthesis at a greater rate when exposed to increased light levels, suggesting that *M. vimineum* may have an advantage over *A. petiolata* in the forest by more readily utilizing high light patches. However, in greenhouse competition, *A. petiolata* seedlings had greater overall mass than *M. vimineum* due to root growth in both light and shaded treatments. Each species appeared to utilize a different strategy to promote invasion. Understanding how each non-native species specifically acts within the ecosystem can be helpful for creating management strategies in areas where simultaneous invasions threaten native biodiversity.

Field Study Methods

<u>Study Site</u> - Natural Area section of Washington Crossing State Park (WCR), Titusville, New Jersey
• Seven transects 100 m in length and 15 m apart were established.
•1 m^2 plots were marked wherever both invasives were co-occurring.

<u>Forest Light Levels</u>
In October 2001, PAR (Photosynthetically Active Radiation) values were recorded in the mid-morning (A.M.) and mid-afternoon (P.M.) for each plot.

<u>Percent Cover</u>
For each plot, the percent cover of each species was visually estimated in November 2001.

<u>Photosynthesis Rates</u>
For *A. petiolata*: In April, July, Sept., and Nov. 2002, photosynthesis rates were recorded on the two largest plants in each plot using the Li-Cor 6400 IRGA Portable Photosynthesis System. PAR values were also recorded.
For *M. vimineum*: After seedlings were established photosynthesis rates were sampled in the field in July and Sept. 2002.

Greenhouse Methods

<u>Seed Collection</u>
•*A. petiolata* seeds were collected from light gaps and closed canopy areas in WCR during July 2001.
•*Eupatorium rugosum* (white snakeroot) seeds were collected during November 2001 to be used as a phytometer.
•*M. vimineum* seeds were collected from light gaps and closed canopy areas in Fall 2001 from WCR and from Hopewell Township, NJ.
•All seeds were cold-stratified at 5˚ C in the dark. *A. petiolata* was stratified for 3 1/2 months; *M. vimineum* and *E. rugosum* were stratified for one month.

<u>Experimental Design</u>
There were seven blocks with 40 pots/block. Each block had five replicates of each treatment (open origin to shaded or unshaded and closed origin to unshaded or shaded. One non-native seedling and one phytometer (*E. rugosum*) were planted in each pot.

<u>Data Collection</u>
In July 2002, photosynthesis rates at both a high (1000 umol/m2/s) and a low light level (84 umol/m2/s) were measured for both species in blocks 1-4. Both study species and the phytometer were harvested for all blocks. Roots were washed and untangled to separate the two plants. Plants were dried at 60˚ C in individual bags and the shoot, root, and total plant mass was determined for all plants.

Introduction

Two non-native species currently invading New Jersey's forests are the biennial herb *Alliaria petiolata* (garlic mustard with C_3 photosynthesis) and the annual grass *Microstegium vimineum* (Japanese stilt grass with C_4 photosynthesis). Both species grow in a wide range of light levels, often in mixed stands, and are assumed to be displacing native plants. Typically, C_4 plants are well adapted to high light environments and can tolerate dryer growing conditions. Conversely, C_3 plants are limited by stomatal closure and may do better in cooler, shaded environments. Despite these theoretical limitations, both *A. petiolata* and *M. vimienuem* are observed growing together in a wide range of light environments. The purpose of this investigation was to understand how each species utilizes available light throughout the growing season to promote invasion and competition against native plants. The study had two main components - a field study investigating how *A. petiolata* and *M. vimineum* performed photosynthetically in situ over the course of a year, and a greenhouse competition study in which the two species' photosynthesis and competitive ability against a native plant were assessed under different light levels. Synthesizing the results from both components will give some insight as to how each species utilizes light levels to promote invasion. Understanding how non-native species invade is important for controlling non-natives and for promoting local and regional biodiversity.

Results – Field Study & Greenhouse Competition

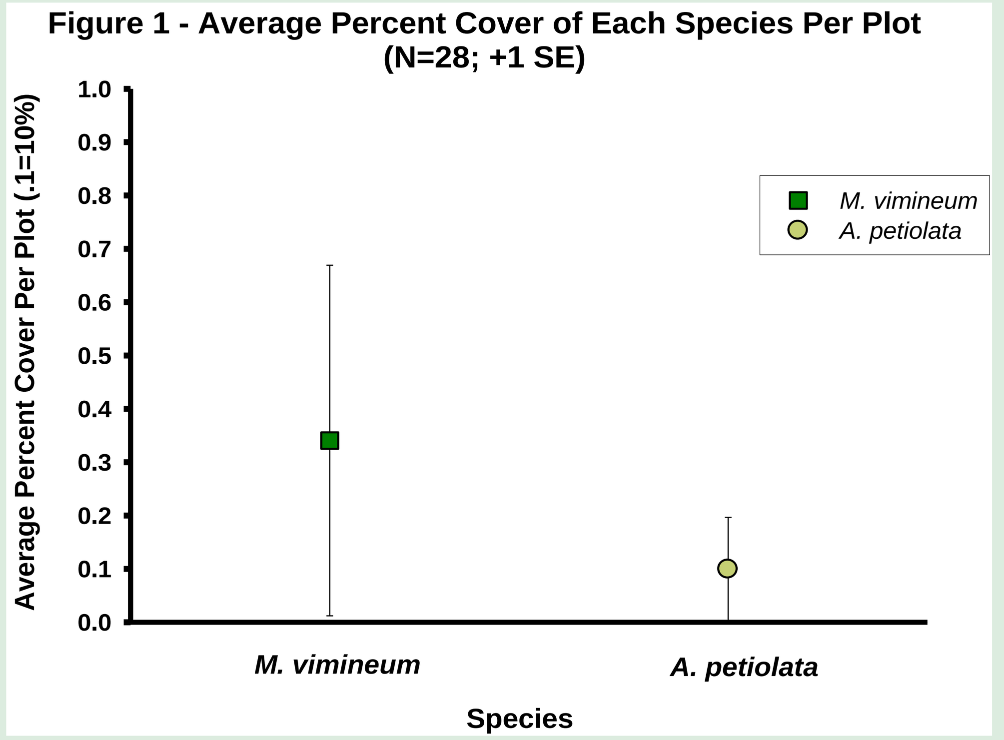


Fig. 1 - Percent cover of *M. vimineum* was greater per plot than the percent cover of *A. petiolata* per plot.

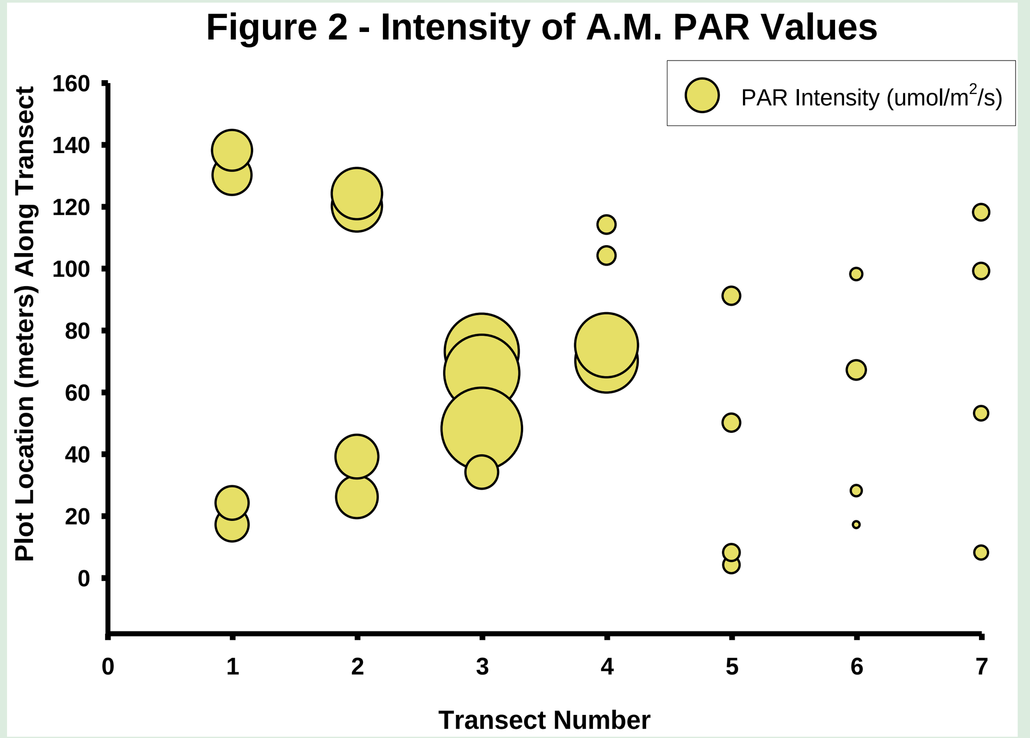


Fig.. 2 - The light environment was variable throughout the study area..

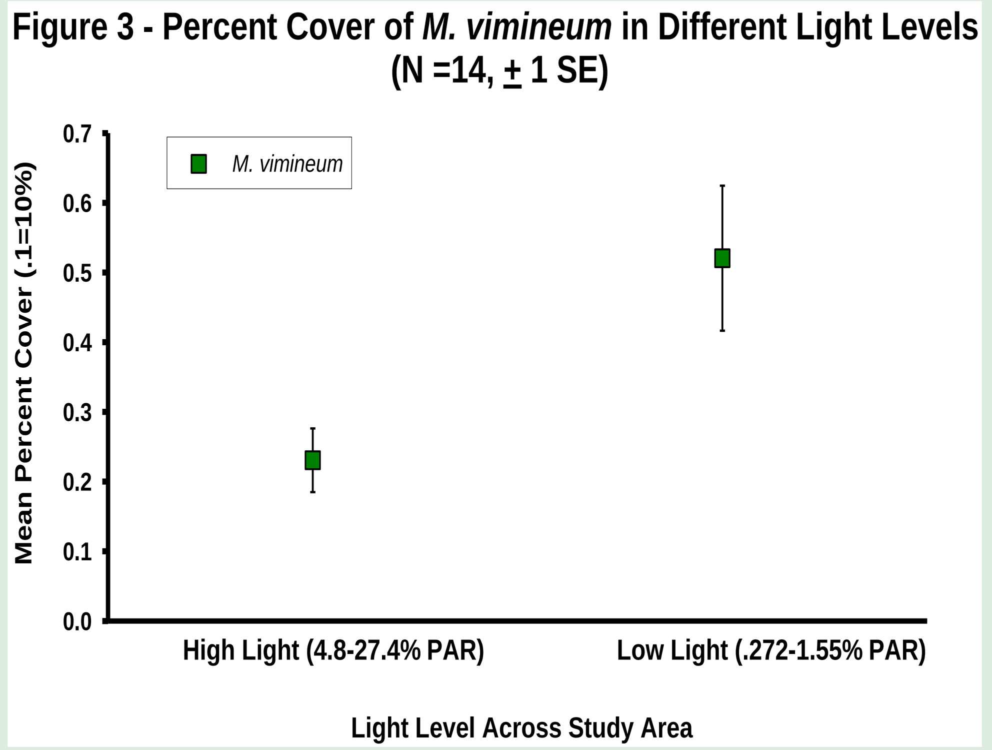


Fig. 3 - Percent cover of *M. vimineum* decreased as light levels increased (t=2.27; P=0.03) . There was no relationship between *A. petiolata* percent cover and light levels in the study area.

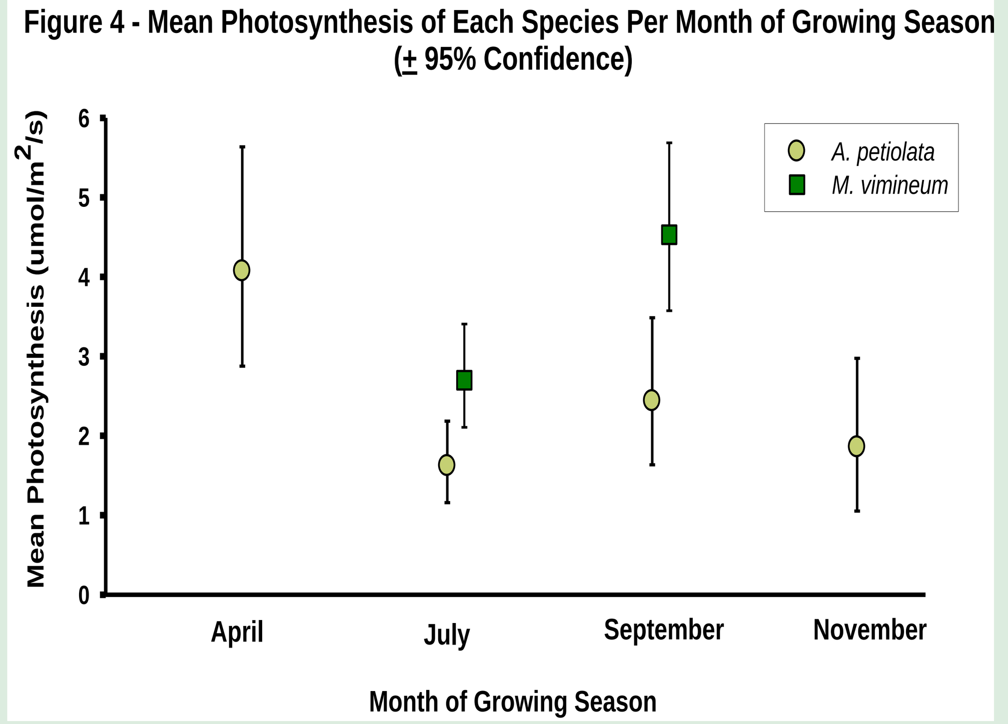
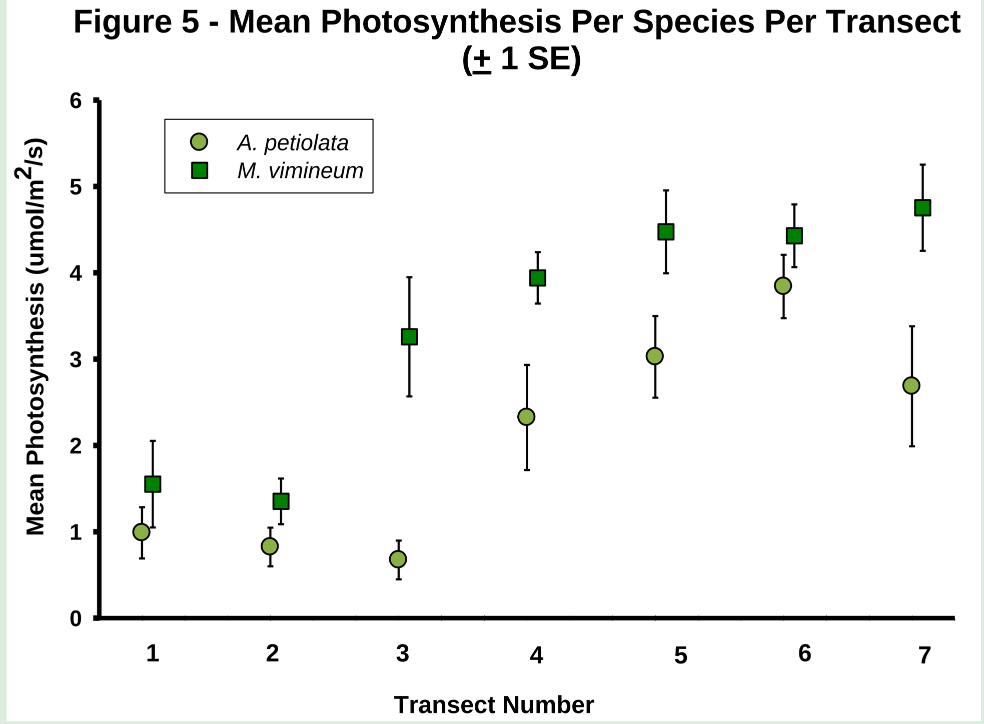


Fig. 4 - The mean photosynthesis rate of *M. vimineum* was greater than the mean photosynthesis rate of *A. petiolata* when the two species were growing together (F=24.45; P<0.0001). The mean photosynthesis rate of *A. petiolata* was highest in April (F=9.39; P<0.0001).

Fig. 5 - Light levels and photosynthesis rates increase across the study area for both species (F=17.40; P<0.0001).



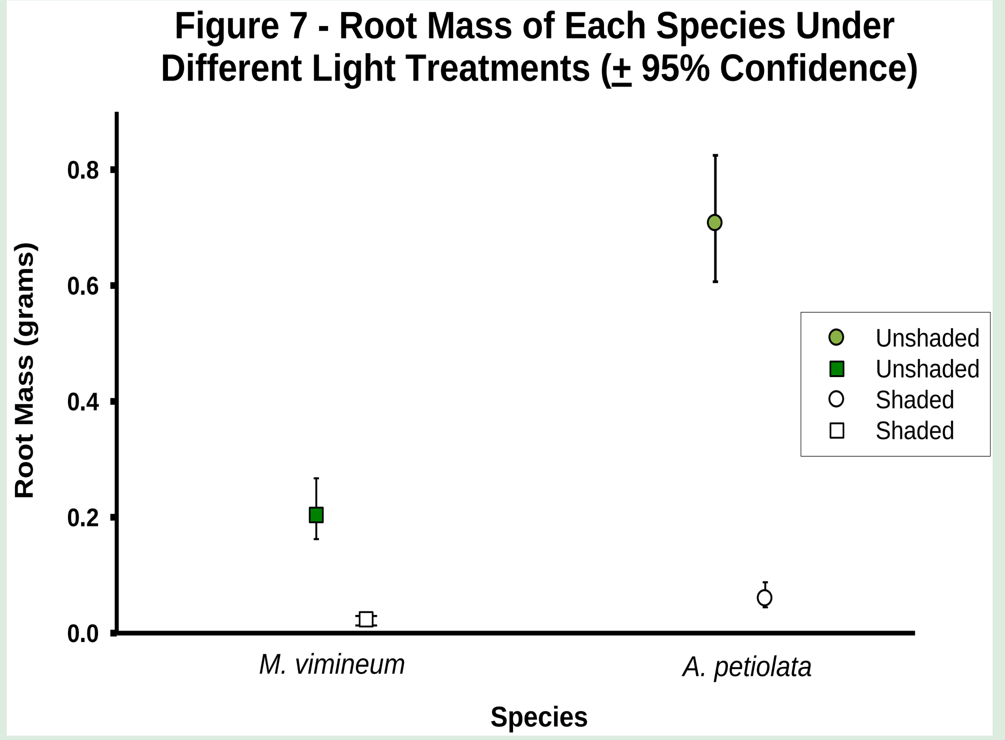
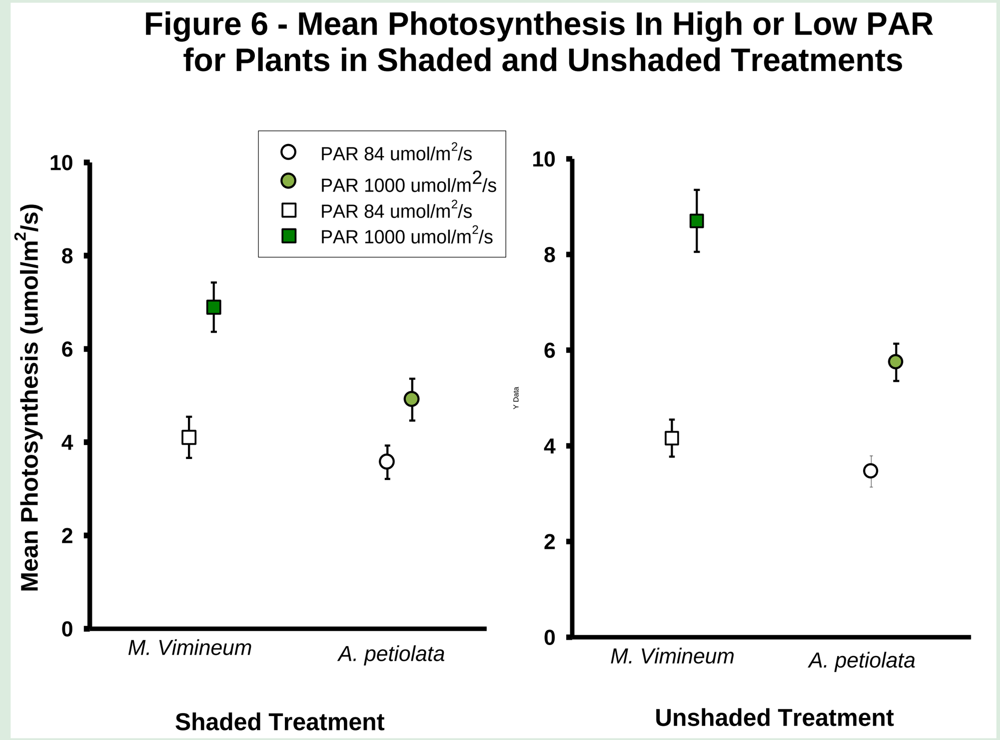


Fig. 6 - Plants grown in both shaded and unshaded treatments had elevated photosynthesis rates when light levels were increased from 84 umol/m2/s to 1000 umol/m2/s PAR (PAR F=61.76; P<0.005). This effect was more pronounced for *M. vimineum* (species*PAR F=27.35; P<0.025).

Fig. 7 - *A. petiolata* produced a significantly larger root mass than *M. vimineum* in both treatments, especially in unshaded treatments (F=69.05; P<0.001).



Discussion

Percent cover of *M. vimineum* in the study forest increased as light levels increased, which directly contrasted the expected percent cover trend for a C_4 species. *A. petiolata* percent cover did not have any relationship to light levels in the forest. This unexpected pattern suggests that *M. vimineum* may be restricted more by another factor tied to light levels in the forest such as soil moisture. Analysis of photosynthesis for the two species showed that although *A. petiolata* and *M. vimineum* occupy the same sites, *M. vimineum* showed a higher photosynthesis rate during the growing season. The field study results were supported by the greenhouse competition experiment, which also showed *M. vimineum* to have a higher photosynthesis rate regardless of light treatment. In the early spring, *A. petiolata* showed a photosynthesis rate comparable to the summer *M. vimineum* rates. Therefore, the two species utilize light during different seasons of the year to promote invasion. *A. petiolata* is photosynthetically active early in the season before *M. vimineum* seedlings establish. During the rest of the season, *A. petiolata* diverts energy to root allocation, which explains the larger root mass observed in greenhouse competition. Since *M. vimineum* is an annual, the species exhibits increased photosynthesis during the summer months to prepare for seed set and dispersal in the late fall. By utilizing light levels for different strategies, *A. petiolata* and *M. vimineum* are able to coexist in forest patches. Understanding how each species makes use of similar light levels to promote invasion can be helpful when considering management strategies in areas where non-native invasions are problematic.